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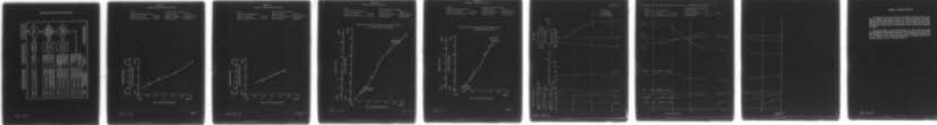
ARMY AVIATION SYSTEMS TEST ACTIVITY EDWARDS AFB CALIF
AH-1G LATERAL FLIGHT PERFORMANCE TEST, (U)
JUN 72 L J HEPLER, J S KISHI, A L WINN
USAASTA-71-43

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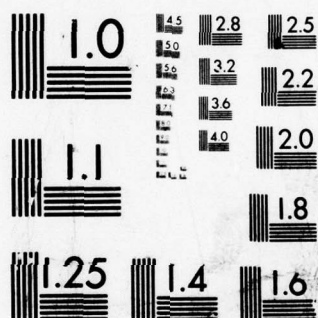
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DEPARTMENT OF THE ARMY
U. S. ARMY AVIATION SYSTEMS TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

30 JUN 1972

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SUBJECT: AH-1G Lateral Flight Performance Test, USAASTA Project
No. 71-43

Commanding General
US Army Aviation Systems Command
ATTN: AMSAV-EF
PO Box 209
St. Louis, Missouri 63166

LEVEL

NOTE
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1. REFERENCES. See inclosure 1.
2. BACKGROUND. The AH-1G lateral flight performance test was directed by the US Army Aviation Systems Command (AVSCOM) in Test Directive No. 71-43 (ref 1, incl 1). This directive was a result of a request by the US Army Combat Developments Command (USACDC).

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3. TEST OBJECTIVE. The objective of this test was to evaluate the lateral flight performance of the AH-1G helicopter equipped with the tractor tail rotor. An additional objective was to evaluate the feasibility of the lateral flight maneuver.

4. DESCRIPTION. The AH-1G helicopter, manufactured by Bell Helicopter Company (BHC), is an attack helicopter which incorporates a narrow fuselage (36 inches), stub wings with four external stores stations, and an integral chin turret. Tandem seating is provided for a two-man crew. The rotor system consists of a two-bladed, semirigid, "door-hinge" type main rotor and a tractor antitorque tail rotor. The helicopter is powered by a Lycoming T53-L-13 turboshaft engine rated at 1400 shaft horsepower (shp), under standard-day, sea-level conditions, derated to 1100 shp by the main transmission torque limit. The flight control system is of the mechanical, hydraulically boosted, irreversible type with a three-axis stability and control augmentation system (SCAS). Conventional helicopter controls are provided with the exception of sidearm collective and cyclic controls in the forward cockpit. The design gross weight of the AH-1G is 6600 pounds, and the maximum gross weight is 9500 pounds. More detailed AH-1G information and aircraft limits are presented in the operator's manual (ref 2, incl 1).

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5. SCOPE OF TEST. Six flights were conducted in 6.1 hours in helicopter S/N 67-15726 at Edwards Air Force Base, California, from 14 December 1971 to 25 January 1972. Tests were conducted with four XM159 rocket pods as wing

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Albert L. /Winn

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stores (heavy-hog configuration). The rocket pods were loaded with dummy rockets to achieve gross weights of 8500 and 9500 pounds and an aft center of gravity (cg). Rocket pods were rebalanced between maneuvers to compensate for fuel burnoff. Limits established in the AH-1G operator's manual (ref 2, incl 1) were used during testing. A 5-percent control margin remaining in any flight control was established as a performance limit. Tests were conducted in stable air with surface winds less than 3 knots.

6. METHOD OF TEST. a. Lateral flight performance testing was conducted by establishing an out-of-ground-effect (OGE) hover and then applying lateral cyclic control to attain a roll attitude. Velocity and acceleration were recorded while attempting to maintain pitch, roll, and yaw attitudes constant. Direction-of-flight reversals were evaluated by accelerating laterally until reaching a limiting condition and then applying lateral cyclic control to decelerate and then accelerate in the opposite direction. Rate and method of lateral control application were varied and evaluated to determine the effects of technique.

b. The flight test data were recorded by an oscillograph and from test instrumentation installed in both the pilot and copilot panels. Data were also recorded by ground space-positioning equipment (Askania cinetheodolite). A qualitative evaluation was made of the handling qualities of the aircraft and pilot workload required during the maneuvers. Ratings were assigned to the various phases of the maneuver using a Handling Qualities Rating Scale (HQRS) (incls 2).

7. **CHRONOLOGY.** The chronology of the AH-1G lateral flight performance test program is as follows:

Test directive received	26	October	1971
Test aircraft received	1	December	1971
Flight tests initiated	10	December	1971
Flight tests completed	25	January	1972
Verbal report submitted by telephone	16	February	1972

8. **RESULTS AND DISCUSSION.** a. General. The lateral flight performance of the tractor-tail-rotor-configured AH-1G helicopter was evaluated at gross weights of 8500 and 9500 pounds. The AH-1G is capable of 0.53g and 0.38g accelerations in right and left lateral flight, respectively, at 8500 pounds. At a 9500-pound gross weight, acceleration was 0.23g to the right and 0.20g to the left. Aircraft handling qualities and time required to attain maximum lateral velocity are dependent upon rate and type of control application. A step-type lateral control input permitted rapid attainment of accelerating attitude but produced yaw oscillations which resulted in loss of directional control and caused high pilot workload in stabilizing power and aircraft attitude. Ramp inputs delayed establishment of the accelerating attitude. A modified pulse input induced negligible roll and yaw oscillation and produced rapid establishment of the desired roll attitude. Direction-of-flight

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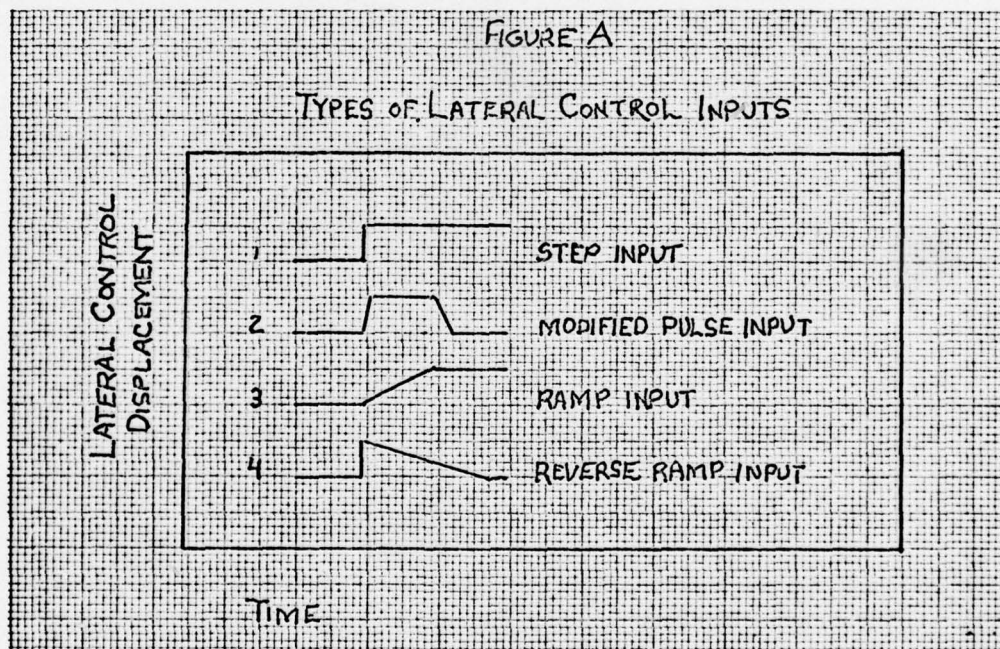
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reversals induced large power transients that frequently exceeded the transmission torque limits. Precise heading and pitch attitude could not be maintained during the reversals. Airspeed in lateral flight could not be determined without special airspeed measuring devices. The sideward airspeed limit was exceeded frequently in left lateral flight with no warning or cue to the pilot that the limit had been reached.

b. Lateral Flight Performance.

(1) Maneuver Entry Effects: Four entry techniques were evaluated to determine the effects of maneuver entry on aircraft performance. The lateral control inputs used are shown in figure A: (1) step input, (2) modified pulse, (3) ramp input, and (4) reverse ramp input. The rate and type of control input varied the time to achieve the desired accelerating attitude from 1 to 3 seconds, resulting in a variation in aircraft lateral velocity at a specific time. Steady-state acceleration was a function of roll attitude and relatively unaffected by entry technique. The modified pulse input was used during the evaluation to obtain performance data.



(2) Acceleration: Steady-state acceleration as a function of roll attitude, at gross weights of 8500 and 9500 pounds and an aft cg, is presented in figures 1 and 2, inclosure 3. The maximum steady-state acceleration was 0.53g in right lateral flight at 8500 pounds and at a roll attitude of 32 degrees. An acceleration of 0.38g was attained in left lateral flight at 8500 pounds and a 25-degree roll

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attitude. At 9500 pounds, 0.23g was attained in right lateral flight with a 15.4-degree roll attitude, and 0.20g in left lateral flight at a 17.7-degree roll attitude. Acceleration data were obtained from an Askania cinetheodolite. Acceleration in lateral flight at 9500 pounds was limited by the main transmission torque limit. At 8500 pounds, right lateral acceleration was limited by pilot workload and aircraft roll attitude beyond which safe flight was doubtful. Left lateral acceleration was limited during maneuver entry by tail rotor control necessary to maintain aircraft heading.

(3) Velocity: Velocity as a function of roll attitude and gross weight is presented in figures 3 and 4, inclosure 3. To minimize the effects of maneuver entry technique, data are shown at 8 seconds following start of aircraft lateral motion. Table 1 shows the time required to reach limit sideward velocity at the gross weights tested.

Table 1. Time to Reach Limit Airspeed.

Gross Weight (lb)	Direction of Flight	Roll Attitude (deg)	Time ¹ to 30 KTAS ² (sec)
8500	Left	24.7	4.7
	Right	31.8	3.6
9500	Left	17.7	8.0
	Right	15.4	7.5

¹Time measured from start of lateral motion.

²A 30-knot-limit sideward velocity (ref 2, incl 1).

c. Lateral Flight Flying Qualities.

(1) Steady-State Acceleration: The maneuver entry techniques described in paragraph 8b(1) were evaluated to determine effect on aircraft handling qualities. Rapid lateral control inputs (step and reverse ramp) permitted rapid roll to the approximate attitude desired but required the pilot to make several subsequent inputs in all controls to precisely establish the desired attitude. Slower lateral control (ramp-type) inputs permitted precise transition to the desired attitude but prolonged the entry. The modified pulse input reduced pilot workload as compared to the step and reverse ramp inputs and permitted rapid establishment of the desired accelerating attitude.

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(2) Roll Attitude Control: Ease of establishment of the accelerating attitude for lateral acceleration in the AH-1G helicopter was evaluated for the several techniques. Rapid lateral control inputs (step-type and reverse-ramp-type inputs) caused small roll oscillations which required several control inputs to stabilize at the desired attitude. Ramp inputs produced negligible roll oscillations but delayed attainment of the accelerating attitude. Modified pulse inputs produced smaller roll oscillations than the step input but reduced time to achieve desired roll attitude as compared to the ramp input. At translational velocity, approximately 12 knots, additional lateral inputs were required to maintain the desired attitude. Lateral accelerations at roll attitudes in excess of 20 degrees required several rapid control inputs due to rapidity at which the trim change occurred. Moderate pilot compensation was required during lateral acceleration to maintain precise roll attitude (HQRS 4), a shortcoming which should be corrected for improved mission capability.

(3) Pitch Attitude Control: Longitudinal control inputs were made in an effort to maintain pitch attitude constant during lateral flight testing. Pitch attitude changes during maneuver entry and during the acceleration were small (1/2 to 1-1/2 degrees). Aircraft pitch attitude during maneuver entry was relatively unaffected by technique used to enter lateral accelerated flight. Minimal pilot compensation was required to maintain desired pitch attitude during entry and lateral acceleration (HQRS 3).

(4) Directional Control:

(a) Directional control inputs were made during AH-1G lateral accelerations in an effort to maintain constant aircraft heading. Tests were conducted with the SCAS yaw channel disengaged to preclude uncommanded directional control inputs and to obtain maximum performance of the aircraft. Qualitative testing in the AH-1G helicopter with SCAS ON indicated that uncommanded yaw SCAS inputs degraded lateral flight performance.

(b) A time history of typical directional control motions is shown in the first portion of figure 5, inclosure 3. Accompanying a modified pulse-type right lateral control input was a requirement for left pedal which decreased as right lateral motion began. As right lateral velocity increased above approximately 10 knots, increasing left pedal was required until an approximate 5-percent control margin remained at the limit lateral airspeed.

(c) Left lateral accelerations were characterized by a requirement for left pedal during maneuver entry. The requirement for left pedal slowly decreased as velocity increased to approximately 18 knots. A sharp discontinuity in directional control requirement occurred at approximately 18 knots which was characterized by a decrease of approximately 1.5 inches in left pedal, yaw excursions of approximately 10 degrees, small deviations in pitch and roll attitudes, and a small

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decrease in power required to maintain level flight. Precise heading control could not be maintained in left lateral flight with extensive pilot compensation (HQRS 6), a shortcoming, correction of which is desirable for improved mission capability.

(5) Power Train Component Failure: High tail rotor power is required during the OGE hover and increased tail rotor power is required during lateral flight maneuver entry and during direction-of-flight reversals. High power train component failure rates were reported in the Phase D testing of the AH-1G (ref 4, incls 1). Two intermediate tail rotor gearboxes (42 degrees) were replaced during lateral performance testing due to excessive wear. The excessive failure rate of the intermediate gearbox is a deficiency, correction of which is mandatory for safe mission accomplishment.

(6) Altitude Control: Lateral flight testing was conducted from OGE hover at approximately 100 feet above ground level. Collective control was used as required to maintain desired altitude during maneuvers. Altitude variation, as recorded by the Askania cinetheodolite, during maneuver entry and acceleration, was normally very small (approximately 5 feet). External cues to height variations were easily detected and altitude control required minimal pilot compensation for adequate performance (HQRS 3).

(7) Direction-of-Flight Reversals:

(a) Direction-of-flight reversals were evaluated from left and right lateral flight by applying lateral control necessary to achieve an accelerating attitude in the opposite direction while applying longitudinal, directional, and collective control in an attempt to maintain desired flight ground track, aircraft pitch and yaw attitudes, and a constant altitude. A time history of the complete direction-of-flight reversal maneuver is presented in figure 5, inclosure 3. Various lateral control techniques were used during direction-of-flight reversals to minimize overcontrolling the aircraft. Rates of reversal were varied from an approximate 5-degree per-second (deg/sec) to a 20-deg/sec roll rate. The slow reversals required lateral control application as much as 3 seconds prior to reaching limit lateral velocity to prevent loss of directional control in right lateral flight or exceeding the lateral velocity limit. The result was an excessive time to attain a decelerating attitude, decelerate, and begin acceleration in the opposite direction. A roll rate of 20 deg/sec permitted lateral accelerations to near limit lateral velocity and reversals without loss of directional control. Reversals were characterized by large yaw excursions (20 to 30 degrees), large power changes, and relatively large pitch excursions (5 to 7 degrees). Precise heading and pitch attitude control could not be maintained during slow or rapid direction-of-flight reversals from maximum lateral acceleration attitudes with maximum tolerable pilot compensation (HQRS 7), a deficiency, correction of which is mandatory for mission accomplishment.

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(b) Excessive torque transients up to 10 pounds per square inch (psi) above transmission torque limit of 50 psi occurred during the direction-of-flight reversal, a deficiency which affects safety-of-flight and correction of which is mandatory prior to flights by operational pilots.

d. Feasibility. An analysis of lateral flight performance, aircraft handling qualities, and the application of the lateral flight maneuver was conducted to determine the feasibility of this maneuver as an effective combat tactic. Within the scope of this evaluation and the current production state of the art, the lateral flight acceleration maneuver is not feasible as an operational maneuver. A brief discussion of each of the factors considered is presented below:

(1) Airspeed Determination: An experimental lateral low airspeed system (incls 4) was installed and calibrated for the lateral performance testing to provide the pilot an accurate, real-time, lateral airspeed indication. In spite of the airspeed system which provided timely and accurate indication of lateral velocity, the lateral airspeed limit was consistently overshoot during steady-state accelerations at roll attitudes above 15 degrees. A comparison was made between the actual airspeed and airspeed estimates made by various aviators. Estimates varied from 7 to 15 knots lower than actual airspeed. Erroneous airspeed estimates by the pilot in combat would result in frequent flights outside the established helicopter flight envelope. Lack of a sideward airspeed system is a safety-of-flight deficiency, correction of which is mandatory for safe mission accomplishment.

(2) Degraded Mode Operation: The lateral flight performance test was conducted with all flight control systems operating (except yaw SCAS). Time did not permit flight evaluation of this maneuver with either hydraulic systems or the complete SCAS inoperative.

(a) The AH-1G helicopter has a dual hydraulic system. Failure of the number-one system causes loss of tail rotor control hydraulic boost, would degrade mission performance, and may dictate termination of the mission. Failure of the number-two hydraulic system causes no loss of flight control hydraulic power. A dual hydraulic failure during the conduct of this maneuver would probably cause loss of aircraft control. The lateral flight maneuver should be terminated upon failure of either hydraulic system.

(b) An inoperative stability and control augmentation system in either pitch or roll would probably degrade conduct of the lateral flight maneuver by increasing pilot workload and reducing accuracy of maneuver. A SCAS failure which causes a control hardover during the conduct of the lateral flight maneuver could place the aircraft in an attitude from which recovery would not be possible. A maneuver from which recovery is doubtful in the event of a SCAS hardover failure is not feasible.

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(3) Engine Failure: Height-velocity testing of the AH-1G (ref 3, incl 1) was conducted to determine the safe flight envelope for the AH-1G in the event of engine failure. The height-velocity report concluded that a safe autorotational landing may not be accomplished following an engine failure at zero to 30 knots between 20 and 465 feet above ground level. The lateral flight maneuver, as proposed, would compromise flight safety by requiring the entire maneuver to be conducted in an unsafe regime.

(4) Pilot Workload: The pilot workload under ideal test conditions was high (paras 8c(4)(c) and 8c(7)(b)). During qualitative tests in gusty winds up to 18 knots, pilot workload was considerably increased. In combat, the added requirements to monitor radio communications, conduct surveillance of the enemy situation, and maintain terrain and obstacle clearance while maintaining perseverance under fire, may produce an intolerable pilot workload.

(5) Power Management: Lateral performance testing was conducted with a rotor speed of 324 rpm and collective control was applied in an attempt to maintain level flight within the operator's handbook established torque limit of 50 psi (ref 2, incl 1). The limit torque was inadvertently exceeded on several occasions during testing when pilot workload became high with the task of maintaining aircraft attitudes. Constant reference to the cockpit indicator to insure that power is maintained within limits degrades precision in conducting the maneuver and increases pilot workload. The requirement for closely monitoring power occurs when pilot workload is highest during the maneuver. Critical power management during the lateral flight maneuver would impose an intolerable workload on the pilot.

(6) Lateral Flight Distance: An analysis and evaluation of the distances traveled during the lateral flight maneuver was conducted. Theoretical travel distances are shown in table 2 for accelerations from zero to 30 and 35 knots and deceleration to zero at four rates of acceleration/deceleration. Actual distances traveled during this test were significantly greater than the theoretical values shown in table 2. For example, at a 9500-pound gross weight, the distance required to accelerate at maximum acceleration (para 8b(2)) to limit lateral airspeed was 275 feet in right lateral flight and 287 feet to the left. Eight seconds following initiation of the lateral flight maneuver, the aircraft had only traveled 88 feet right and 62 feet left from the hover point. The distances traveled during the lateral flight maneuver are a function of technique as well as the maximum acceleration and limit lateral envelope airspeed. However, the distances are small, and the aircraft may remain within the beaten zone of an enemy weapon system during the lateral flight maneuver.

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Table 2. Theoretical Lateral Travel Distances.

Acceleration (g)	To 30 Knots ¹ (ft)	Return to Zero Knots (ft)	To 35 Knots ² (ft)	Return to Zero Knots (ft)
0.2	199	398	271	542
0.4	100	200	136	271
0.5	80	159	108	217
0.6	66	133	90	181

¹Limit lateral airspeed, AH-1G (ref 2, incls 1).

²Helicopter specification lateral airspeed (ref 5, incls 1).

9. CONCLUSIONS. a. General. The following conclusions were reached upon completion of the lateral performance test of the AH-1G helicopter configured with a tractor tail rotor:

(1) Within the scope of this test, the AH-1G helicopter equipped with the tractor tail rotor is capable of 0.53g and 0.38g in right and left lateral flight, respectively, at an 8500-pound gross weight, and 0.23g and 0.20g in right and left lateral flight at a 9500-pound gross weight (para 8b(2)).

(2) The AH-1G is capable of attaining the 30-knot lateral velocity limit within 8 seconds following start of lateral motion at a 9500-pound gross weight (para 8b(3)).

(3) Aircraft performance and handling qualities are affected by maneuver entry technique (paras 8b(1) and 8c(1)).

(4) The lateral flight maneuver is not feasible in the AH-1G helicopter as an operational maneuver (para 8d).

b. Deficiencies Affecting Safety of Flight. Correction of the following deficiencies is mandatory for safe mission accomplishment of the lateral flight maneuver:

(1) Excessive power transients exceeding transmission torque limits during direction-of-flight reversals (para 8c(7)(b)).

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(2) Lack of a sideward airspeed indication (para 8d(1)).

(3) Excessive failure rate of the 42-degree gearbox (para 8c(5)).

c. Deficiencies Affecting Mission Accomplishment. Inability to maintain precise heading and pitch attitude control during direction-of-flight reversals is a deficiency, correction of which is mandatory for mission accomplishment (HQRS 7) (para 8c(7)(a)).

d. Shortcomings Affecting Mission Accomplishment. Correction of the following shortcomings is desirable for improved mission capability:

(1) Moderate pilot compensation required to maintain precise roll attitude during lateral acceleration (HQRS 4) (para 8c(2)).

(2) Extensive pilot compensation required to maintain precise heading control in left lateral flight (HQRS 6) (para 8c(4)(c)).

10. RECOMMENDATIONS. a. The deficiencies should be corrected prior to use of the lateral acceleration maneuver by operational pilots.

b. The shortcomings should be corrected as soon as possible.

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c. Lateral flight maneuvers should be terminated upon failure of either hydraulic system (para 8d(2)).

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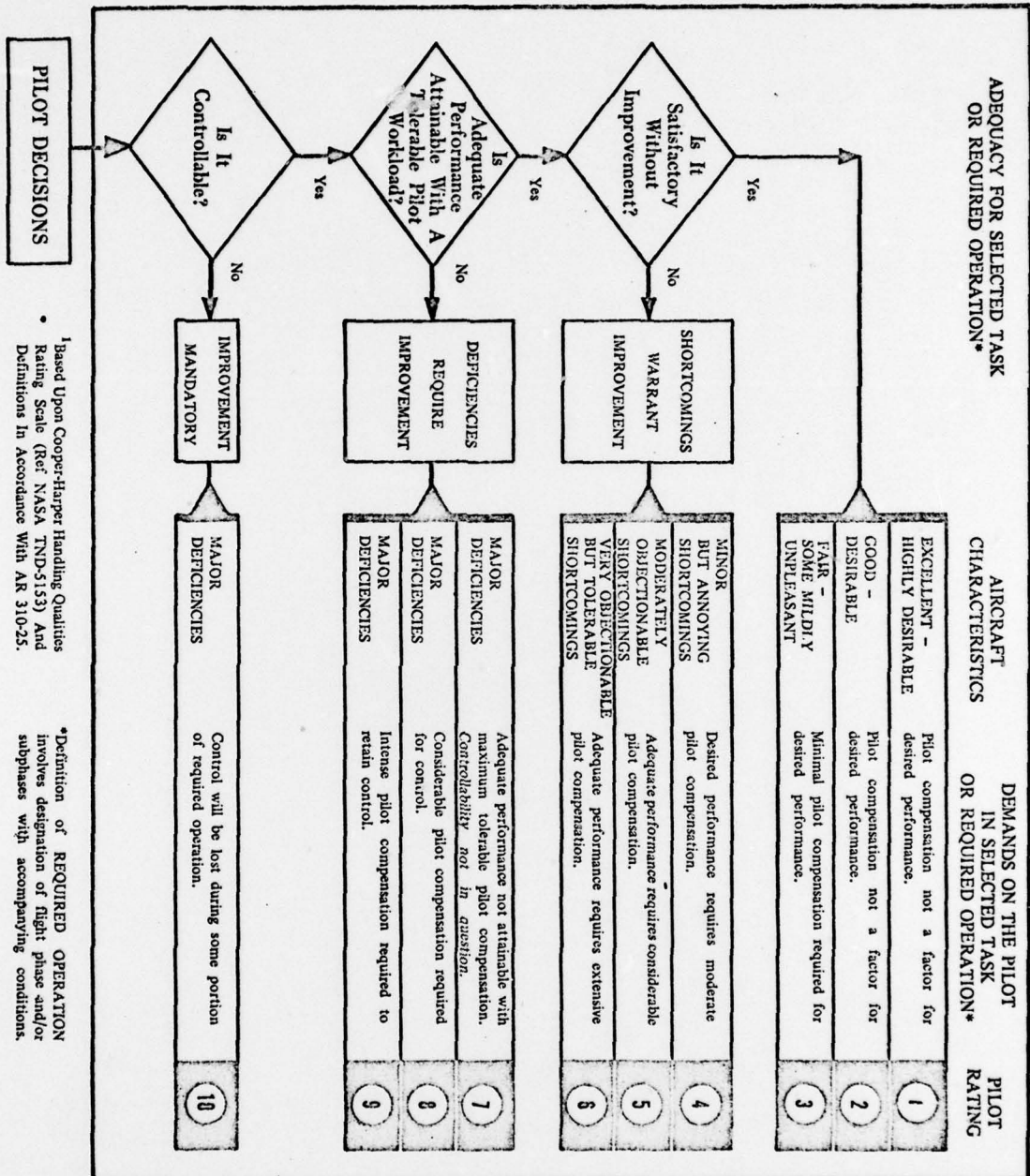
Dean E. Wright
DEAN E. WRIGHT
Colonel, TC
Commanding

REFERENCES

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2. Technical Manual, TM 55-1520-221-10, *Operator's Manual, Army Model AH-1G Helicopter*, 19 June 1971.
3. Final Report, USAASTA, Project No. 69-13, *Height-Velocity Test, AH-1G Helicopter*, February 1971.
4. Final Report, USAASTA, Project No. 69-06, *Engineering Flight Test of the AH-1G Helicopter (HueyCobra), Phase D, Part 1*, December 1970.
5. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements For*, 7 September 1961, with Amendment 1, 3 April 1962.

Incls 1

HANDLING QUALITIES RATING SCALE

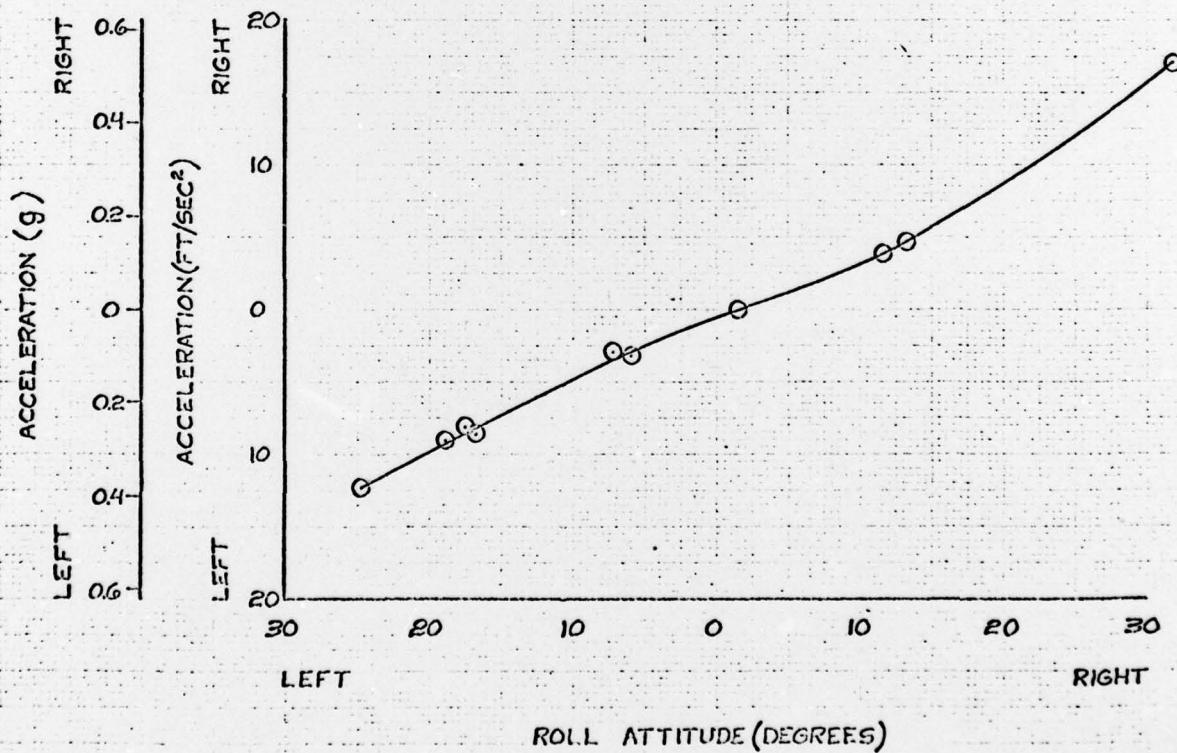


Encls 2

FIGURE 1
LATERAL FLIGHT ACCELERATION

AH-1G
HEAVY-HOG CONFIGURATION
DENSITY ALTITUDE = 2400 FT
FREE AIR TEMPERATURE = 10.2°C

US ARMY S/N 67-15726
GROSS WEIGHT = 8500 LB
CENTER OF GRAVITY = 200.2 IN. (AFT)
ROTOR SPEED = 324 RPM



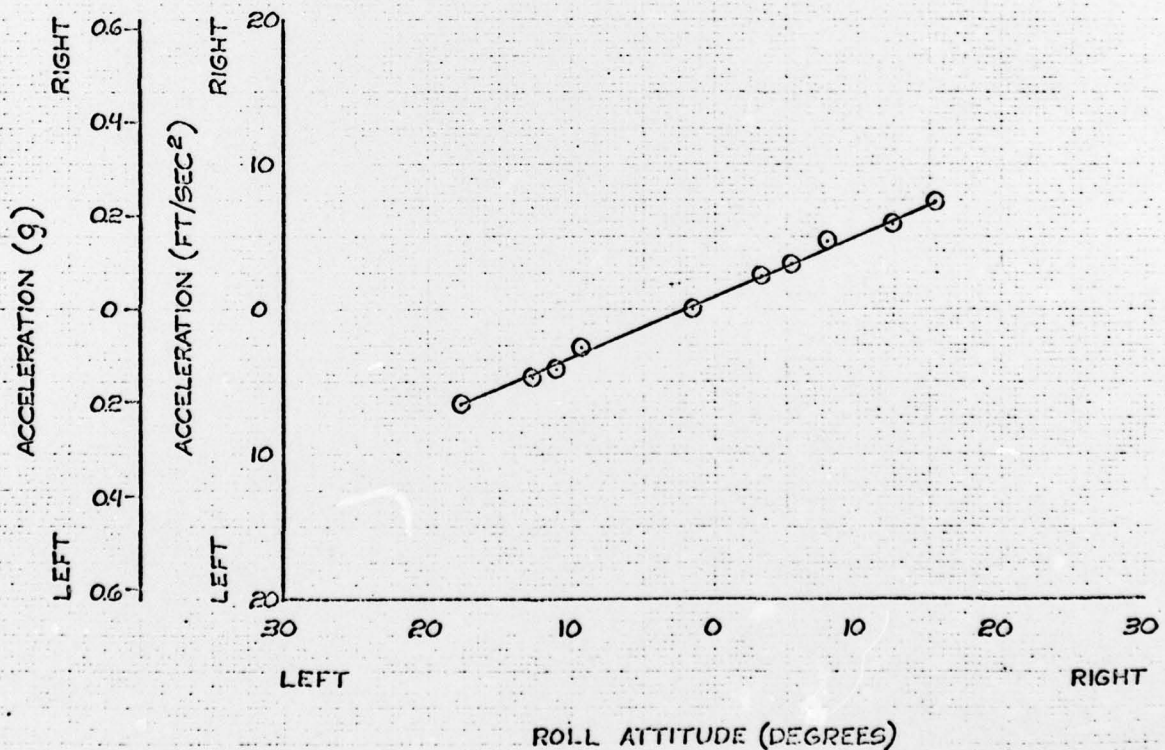
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FIGURE 2
LATERAL FLIGHT ACCELERATION

AH-1G
HEAVY-HOG CONFIGURATION
DENSITY ALTITUDE = 2370 FT
FREE AIR TEMPERATURE = 10.3 °C

US ARMY S/N 67-15726
GROSS WEIGHT = 9500 LB
CENTER OF GRAVITY = 200.0 IN. (AFT)
ROTOR SPEED = 324 RPM



Inch 3

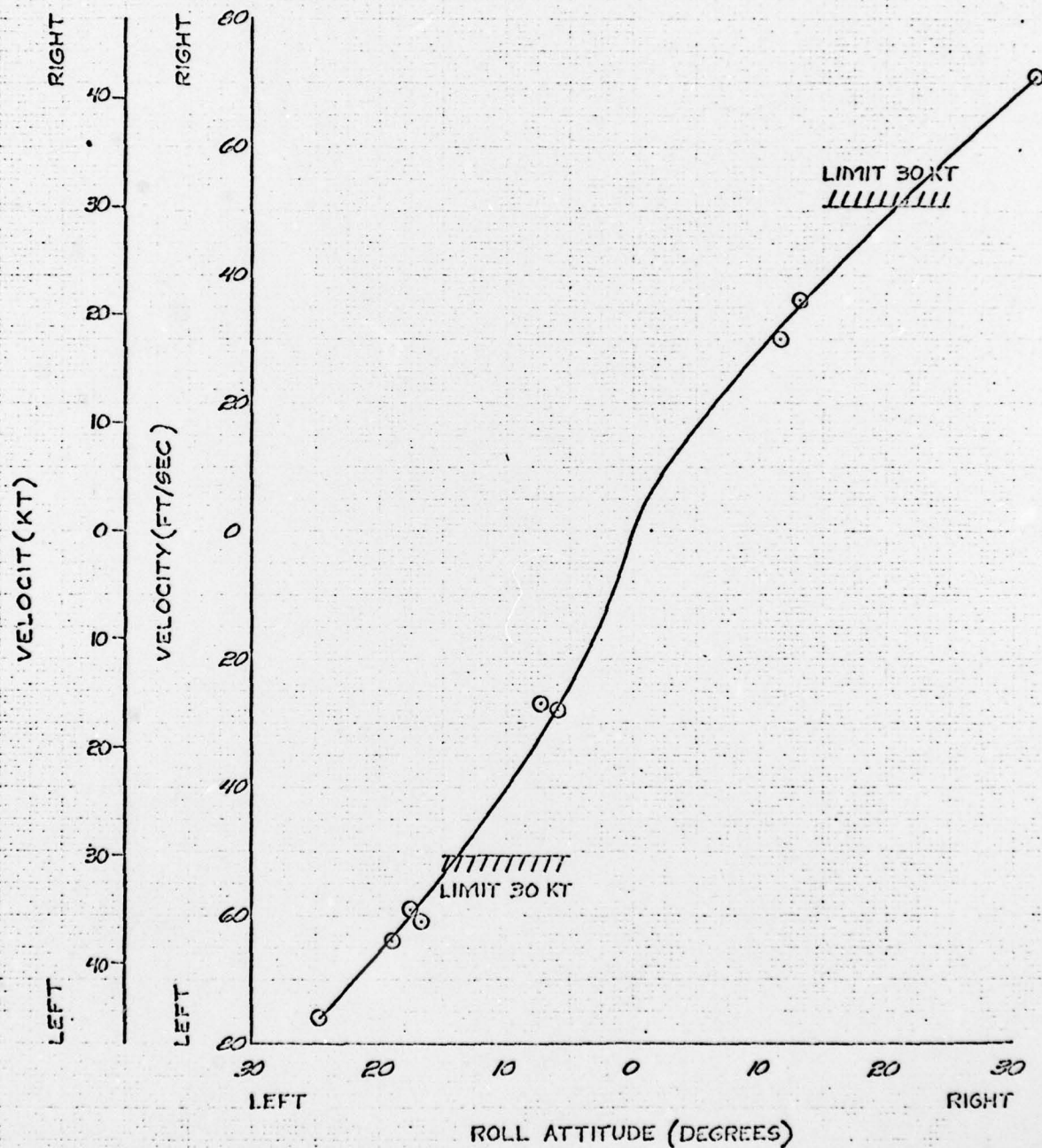
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FIGURE 3
LATERAL FLIGHT VELOCITY

AH-1G
HEAVY-HOG CONFIGURATION
DENSITY ALTITUDE = 2400 FT
FREE AIR TEMPERATURE = 10.2°C

US ARMY S/N 67-15726
GROSS WEIGHT = 8500 LB
CENTER OF GRAVITY = 200.2 IN(AFT)
ROTOR SPEED = 324 RPM

NOTE: VELOCITY AT 8 SECONDS FOLLOWING START OF
LATERAL AIRCRAFT MOTION.



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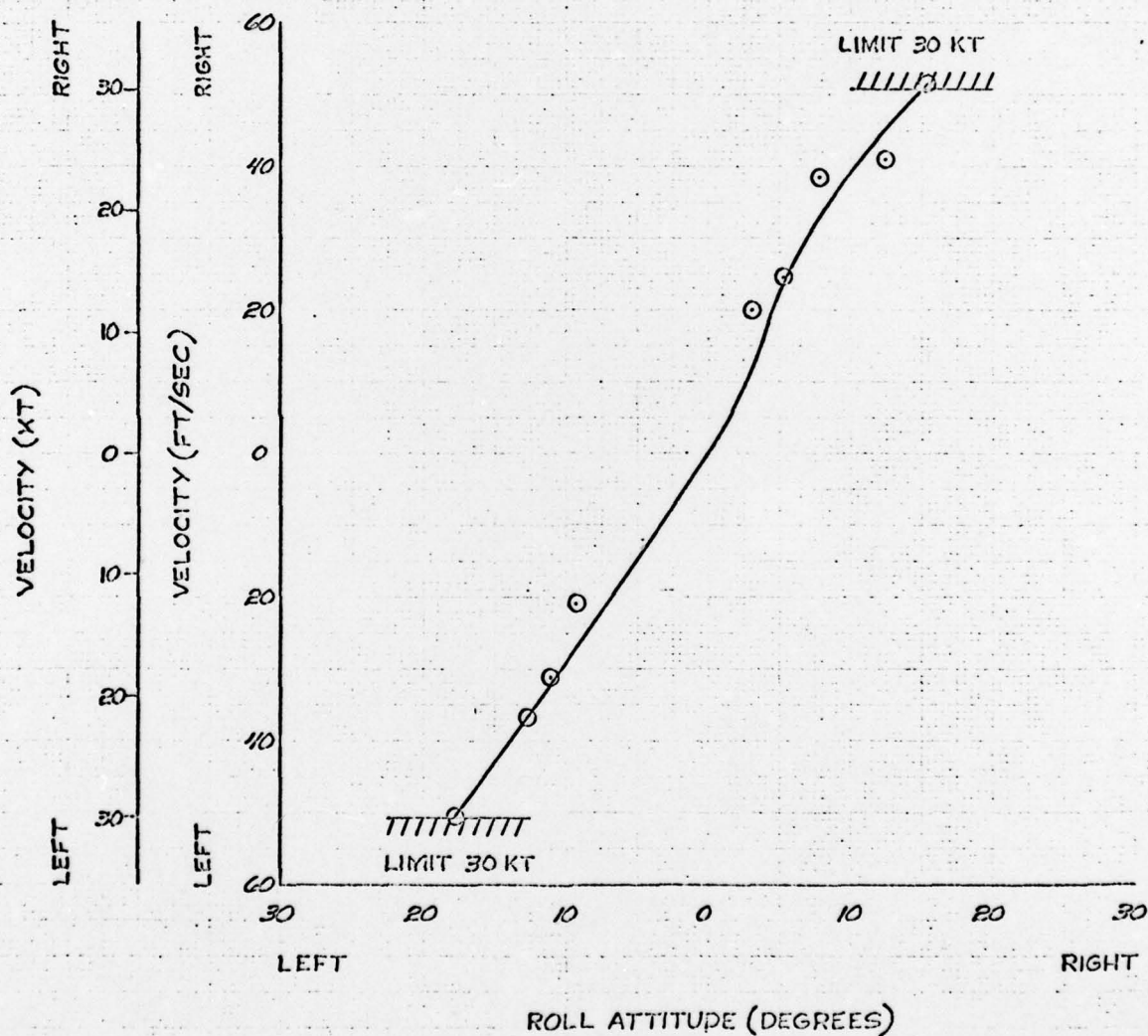
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FIGURE 4 LATERAL FLIGHT VELOCITY

AH-1G
HEAVY-HOG CONFIGURATION
DENSITY ALTITUDE = 2370 FT
FREE AIR TEMPERATURE = 10.3°C

US ARMY S/N 67-15726
GROSS WEIGHT = 9500 LB
CENTER OF GRAVITY = 200.0 IN (AFT)
ROTOR SPEED = 324 RPM

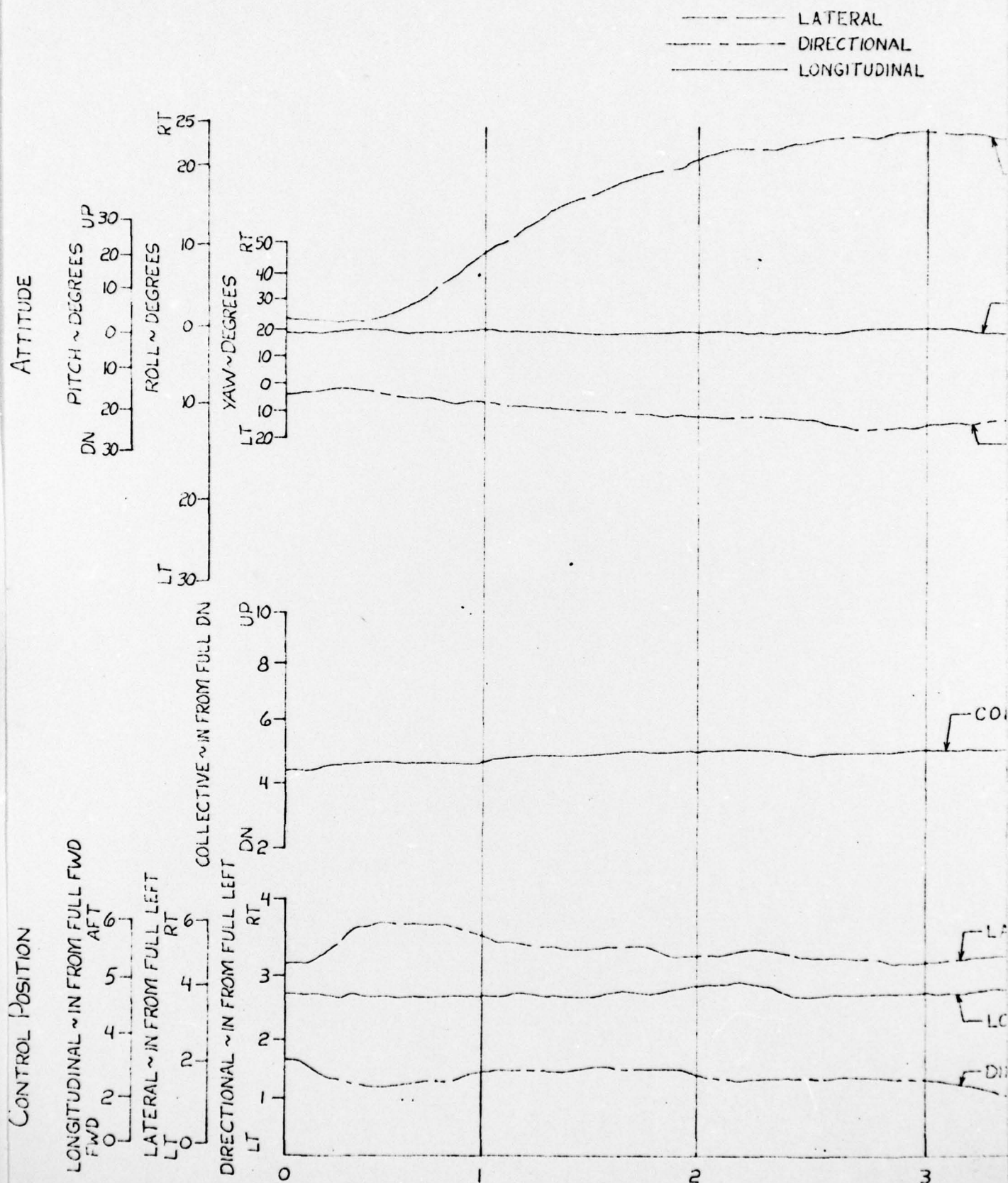
NOTE: VELOCITY AT 8 SECONDS FOLLOWING START OF
LATERAL AIRCRAFT MOTION.



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FIGURE 5



Encls 3

TIME HISTORY OF TYPICAL LATERAL FLIGHT WITH REVERSAL IN DIRECTION

AH-1G

HEAVY HOG CONFIGURATION

DENSITY ALTITUDE = 2370 FT

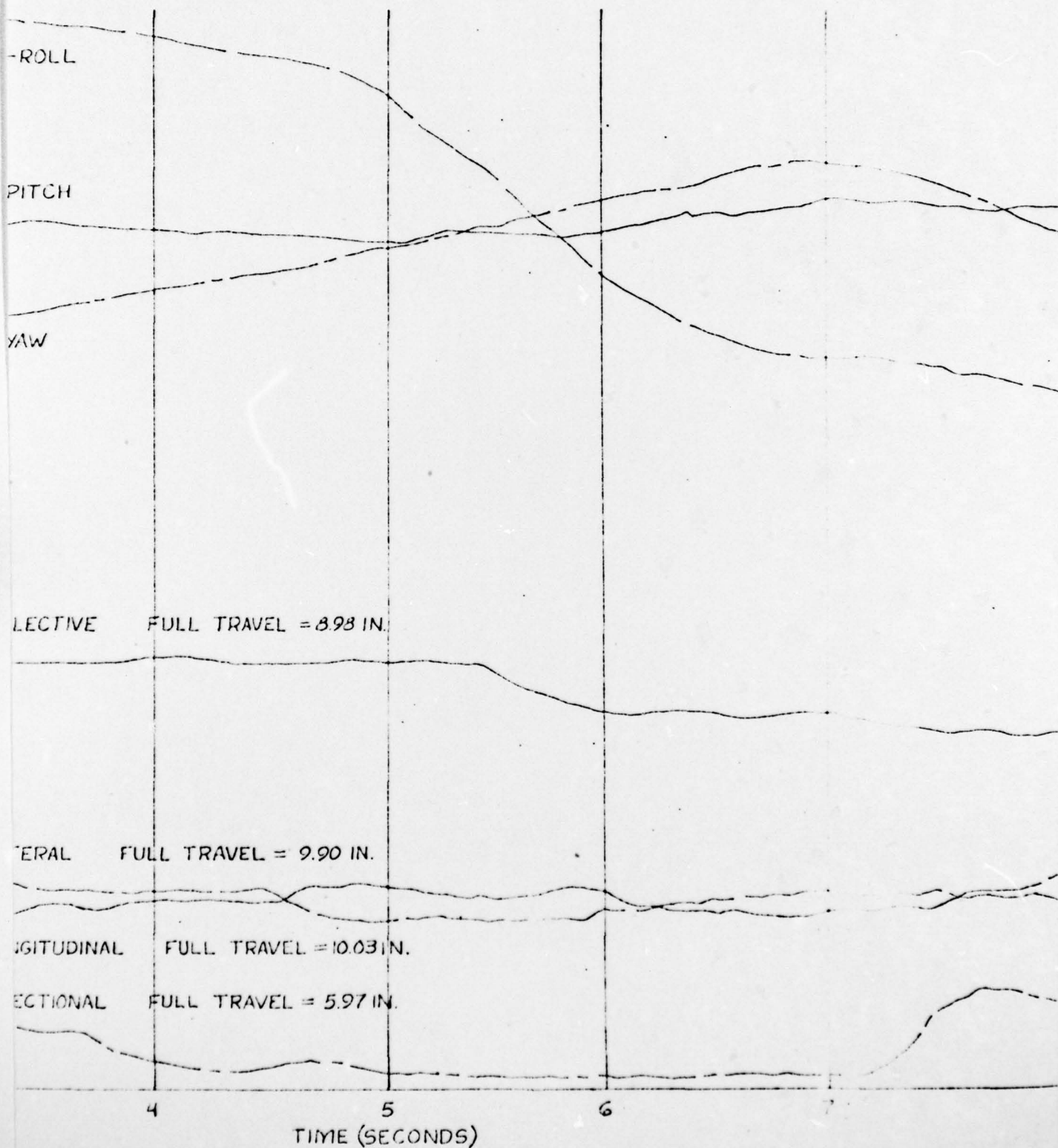
FREE AIR TEMPERATURE = 10.3°C

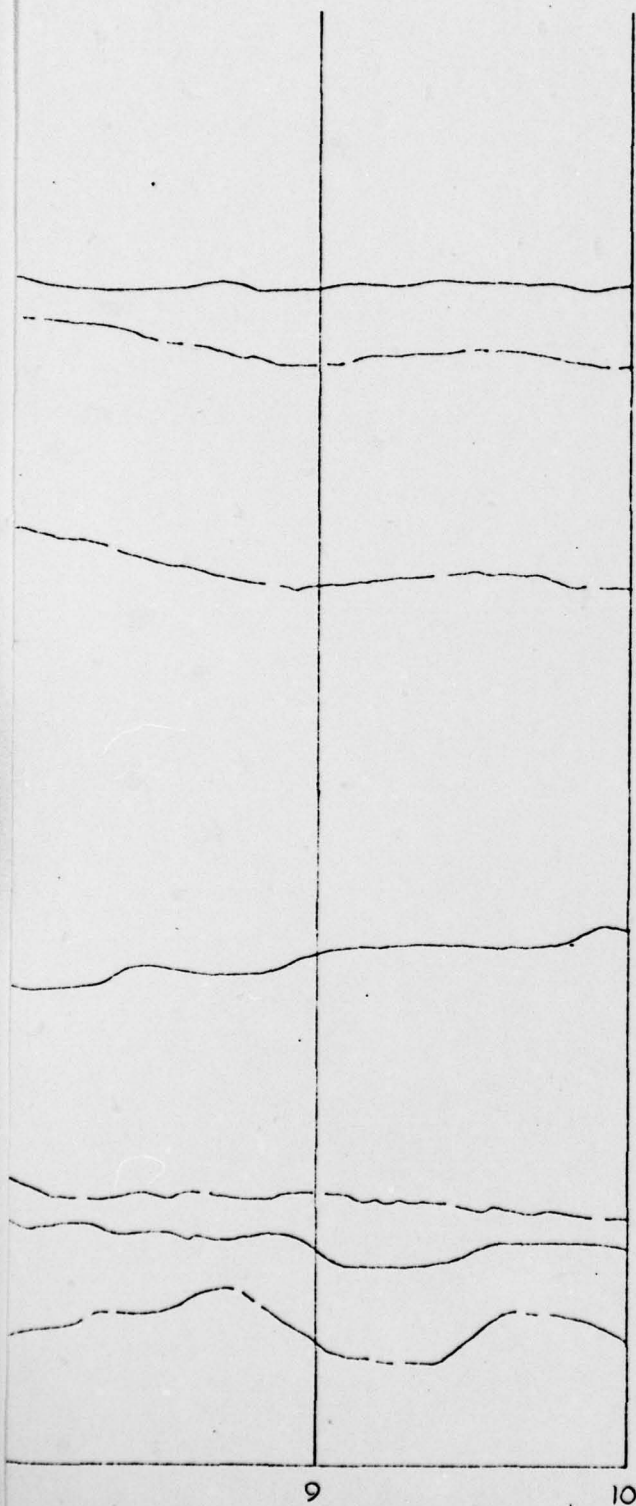
US ARMY S/N 67-15726

GROSS WEIGHT = 9500 LB

CENTER OF GRAVITY = 200 IN (AFT)

ROTOR SPEED = 324 RPM





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LATERAL AIRSPEED SYSTEM

1. The airspeed system used during the lateral flight performance tests was the Elliott helicopter low airspeed sensing and indicating equipment (LASSIE), manufactured by Elliott Flight Automation Ltd., Airport Works, Rochester, Kent, England. The system is based on the principle that the resultant downwash angle and velocity is a function of the airspeed and the rotor induced flow magnitude and angle.
2. The sensor consists of a swiveling pitot-static probe with a guide vane capable of measuring downwash magnitude and angle. The vane aligns the pitot probe with the airspeed in one plane only. Therefore, airspeed is measured only along one axis. In addition to the swiveling pitot-static probe, the system consists of an airspeed computer unit and a cockpit indicator.

Incl 4